REMARKS

Applicants submit a revised specification and new Abstract curing the objections set forth in the Office Action. The revised specification includes additional descriptive matter, in conformance with the drawings.

Revised formal drawings for FIGS. 4, 8, 10, and 11 are also attached, together with marked-up copies for the Examiner's convenience, so that the drawings and specification conform with each other. To summarize the changes to the drawings, in FIG. 4, reference numeral 300 is inserted, and the locations of the lead lines for reference numeral 400 are revised. In FIG. 8, the locations of reference numerals 702 and 703 are corrected, and descriptive legends are provided. In FIG. 10, reference numerals 701 and 702 are changed to 702 and 703, respectively. Also, the lead lines for A and B are corrected, and A', B', and reference numerals 300 and 706 are inserted. In Fig. 11, both storage areas are now identified as 703, and reference numeral 400 is inserted. In FIG. 12c, both storage areas are now labelled 703, and the locations of reference numerals 1216 and 1212 are corrected.

The undersigned attorney for applicants certifies that the substitute specification, new Abstract, and revised drawings do not include new matter. The Examiner is requested to approve the accompanying replacement figures.

Applicants have amended claims 1 and 5 to include the subject matter of claims 2 and 7, respectively, and have

canceled claims 2, 7, 15 and 16 to expedite prosecution. Claims 1-13 have been amended to overcome the objections to the claims set forth in item 4, page 3 of the Office Action. Claims 3, 4 and 6 have been amended to define active method steps. Syntax-type errors have been corrected in some of the other claims. Applicants have added claims 16-20 to provide them with the protection to which they are deemed entitled.

Applicants cannot agree with the statement in the Office Action that Shaath et al., U.S. patent 6,546,384, anticipates the search algorithm requirement of claims 2, 7 and 10. The search algorithm requirement of claims 2 and 7 has been incorporated into claims 1 and 5, respectively. Claim 10, as written, included a search algorithm requirement. Claim 1 now requires the step of locating target data that is part of the logical data by applying a search algorithm to the data position information stored in the centralized storage area. The search algorithm is configured to locate the target data. Claim 5 now requires locating target data on the tape by applying a search algorithm to the data position information stored in the centralized storage area. The search algorithm is configured to locate the target data that is part of the logical data. Claim 10 requires the target data on the tape to be located by using information in the centralized storage area and the search algorithm. The Office Action states column 6, lines 21-24 et seq. of Shaath et al. teaches the application of a search algorithm to the data position

information to locate a target data. Applicants cannot agree. The relied on portion of the reference says:

> Under usual circumstances an index for a tape loaded in the system will be stored in operating memory such as the hard disk. To locate a file, a search of the index in operating memory determines the location of the file. The tape is advanced to the file position and the file is read.

Applicants are unable to determine where the foregoing quotation from Shaath et al. includes a "teaching" or disclosure of a search algorithm for data position information. The foregoing portion of the reference merely says there is a search of the index to determine the location of the file. A search of an index to determine the location of a file is not the same as applying a search request to data position information stored in a centralized storage area, as former claims 2 and 7 required, and as now required by claims 1 and 5. A search of an index to determine the location of a file is also not the same as a search algorithm to locate target data on a tape, as claim 10 previously required. Claim 10 has been amended to more positively indicate the nature of the search algorithm by saying the search algorithm is for determining the location of the target data on the tape.

If the Examiner persists in saying Shaath et al. discloses the foregoing features of claims 1, 5 and 10, she is requested to indicate more particularly the rationale supporting such a position. If the Examiner is relying on inherency, she needs to bear in mind that she has the burden

of proving by reasoning or evidence the rationale for a rejection based on inherency; Manual of Patent Examining Procedure, Section 2112.

Claims 16-20 include features not disclosed or made obvious by the art of record. Claims 16, 17 and 20 require the reserve storage area to be a volatile memory external to the tape. Claim 16 includes the additional requirement for the volatile memory to be erased in response to the tape being removed from a device for reading the tape. Claims 18 and 19 indicate the tape includes plural parallel tracks and the algorithm derives a physical target position for a track different from the track where the head is positioned in response to indications of logical current and logical target positions.

In view of the foregoing amendments and remarks, favorable reconsideration and allowance are respectively requested and deemed in order.

To any extent necessary, Applicants hereby request an extension of time in which to file this paper. The Commissioner is hereby authorized to charge any omitted fees,

including extension of time fees, or to credit any overpayment to Deposit Account 07-1337.

Respectfully submitted,

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On March 17, 2004

Rose Tyler

ABSTRACT

A byte stream of data is logically partitioned. Data position information relating to the logical data is stored in a reserve storage area. The position information is transferred from the reserve storage area to a centralized storage area that stores information relating to substantially all the partitioned logical data. The position information is used to locate target data using a search algorithm.

~~CENTRALISED~~ CENTRALIZED DATA POSITION INFORMATION STORAGE SYSTEM AND METHOD

~~Field of the Invention~~ Field of the Invention

[0001] The present invention relates to a method of and apparatus ~~of~~ for storing data position information relating to data distributed on a tape data storage device.

~~Background to the Invention~~ Background of the Invention

[0002] In order to store information it is known to use a magnetic tape storage system in which a magnetic tape is wound on reels or spools. These magnetic tape information storage systems are extensively used to back up, archive and store data for future use by a user of, for example, a host user interface or PC.

[0003] A typical magnetic tape storage device 100 is illustrated in Fig. 1. The tape storage device 100 may be a stand alone unit, or may be integrated within a casing of a host computer entity 101. The data storage device 100 is operable to (1) receive data from a host computer entity 101 and store data on a magnetic tape data storage medium, contained within a tape cartridge, ~~and also to~~ (2) read data from cartridges, and (3) input read data to the host computer 101.

[0004] ~~Referring to~~ Fig. 2 ~~herein, there~~ is ~~shown schematically in~~ a perspective external ~~view,~~ view of a typical known tape data storage cartridge 200, comprising a casing 201 containing ~~in this case,~~ a single reel upon which is wound a length of magnetic tape data storage medium. The magnetic tape data storage medium is wound in and out of the cartridge through an aperture 202, onto a reel within the tape data storage device in use.

[0005] ~~Referring to~~ Fig. 3 ~~herein, there~~ is ~~illustrated~~ a schematic~~ally~~ front view of ~~a~~ cartridge 200 inserted into a tape data storage device 100, wherein a length of tape data storage medium 300 is wound from an internal reel 301 of the cartridge, through a series of capstans and rollers 302-305 onto a second reel 306 ~~comprising~~ in the tape data storage device. The tape data storage device comprises a read/write head 307 over which the tape 300 is drawn, in forward and reverse directions, to apply read or write operations of user data to the tape.

[0006] Typically, the tape drive controls the movement of the tape over the write head to record data onto the magnetic tape, and over the read head to generate an electrical signal from which the stored data can be reconstructed. Commonly, the read and write heads ~~may be~~ combined into a single read/write head~~, this head being~~ controlled by the tape drive.

[0007] A length of magnetic tape 300 as known in the art is schematically illustrated in Fig. 4 such that data is recorded ~~onto~~ on the tape in a series of parallel, elongated (i.e., linear) data tracks 400. When ~~an~~ a command is issued ~~by a~~ by host computer 101 to ~~read a~~ read specific target data on the tape the tape drive using a read head must scan the data tracks 400 to locate the position of the target data, thereby allowing the read head to retrieve the data and transfer it back to the host. The tape drive, being configured to ascertain a current position on the tape relative to the Beginning Of Tape or Wrap (BOW), scans the data tracks 400 until the read head passes over a directory 401 positioned at the BOW. In the example ~~shown here~~ of Fig. 4, the directory ~~being~~ 401 is located at the BOW ~~is~~ and configured such that ~~its~~ the directory contents are distributed ~~across~~ along the tape, at the end of each Wrap ~~as shown in Fig. 4~~. The contents of the directory 401 coincide ~~to~~ with the separate data tracks 400, such that the contents of the directory 401 located at the BOW or the EOW are used to allow the tape drive to determine if the target data is contained on a relevant data track. If data position information in the area 401 indicates that the target data is not located in a particular data track, then the drive must continue

reading the data until ~~it~~ the drive comes across the target data. Similar prior art data storage systems ~~utilise~~ utilize a directory stored in a cartridge memory rather than on the tape, and the data ~~being~~ are accessed on tape by a read operation of the cartridge memory.

[0008] When recording data onto a magnetic tape it is known to partition the data into a plurality of data sets, such data sets being distributed across the various data tracks. The partitioning of data into data sets distributed across the data tracks provides a physical position of any one particular data set relative to, for example, the BOW and EOW. Such a physical positioning ~~being~~ is provided ~~as~~ because the data sets are spatially separated along the length of the tape.

[0009] Within one particular data set the data is further partitioned into a series of records and filemarks, such partitioning giving rise to a logical data position for any particular record or filemark.

[0010] Magnetic tape data storage systems known in the art having directories 401 associated with a corresponding data track 400 along the length of a tape, and utilize such directories to store logical data position information as detailed in Fig. 5. A data track 400 ~~is illustrated as having~~ has data 500 distributed ~~across~~ along its length. The data 500 within a data set and positioned on a data track 400 has corresponding data position information stored within the directory 401 as record data position information 501 and filemark data position information 502. Commonly, the directories also contain data position information ~~303~~ 503 relating to the positioning of data sets distributed ~~across~~ along the length of the data track ~~200~~ 400.

[0011] ~~Referring to~~ Fig. 6 ~~there~~ is a schematic diagram of a tape. Fig. 6 is helpful in describing ~~detailed~~ a typical mode of operation of a prior art magnetic tape data storage system ~~having~~ that has received a target data

command from a host. Using the directory 401 located at the BOW, and in particular the contents of the directory located at the BOW and EOW corresponding to a particular data track, the tape drive determines ~~a required~~ the tape motion ~~so as~~ required to position the read head on a data track corresponding to the data track ~~on which~~ where the target data is positioned. The directory ~~contents~~ 401 contains information at the BOW and the EOW. The ~~providing~~ information ~~on~~ indicates the positioning of the target data within this particular data track. As the read head is effectively transported to a new data track as shown in Fig. 6 the tape motion may be such that the read head ~~is being transported~~ moves away from the target data position B. The read head must serially read the data track until ~~it is determined~~ a system associated with the tape determines, using the contents of the directory information at the EOW (as shown in Fig. 6), that the tape motion should be reversed ~~in order~~ to ~~allow~~ access ~~to~~ the target data B. Essentially, each data track information area 401 functions as a map of the logical position of the data to the actual physical position of the data on the tape. The physical position, ~~this~~ data ~~being~~ is partitioned into data sets distributed along the data tracks. Obviously, the more information a directory, located at the BOW contains, the more complete the mapping of the physical position of data on tape.

[0012] However, a prior art storage device having a complete directory (containing information relating to all data on the tape) is restricted by the read speed of the tape drive due to the serial reading operation as detailed in Fig. 6 when the read head ~~traverses~~ moves from, for example, point A^{l} to point B where the target ~~data B~~ data are located. Moreover, a directional change of tape motion is undoubtedly required at some stage of the data retrieval ~~process, this adding~~ process; the directional change adds to the data access time.

[0013] Accordingly, the inventors have identified various problems associated with the employment and ~~utilisation~~ utilization of such magnetic tape

data storage systems as described above and known in the art. The problems identified by the inventors include:

- ~~Utilising~~ Utilizing data position information in a distributed manner (the spatially separated directories 401) results in excess tape motion and, in particular, multidirectional changes. This excessive tape motion inevitably leads to a longer time ~~period~~ being taken from the ~~issuing of~~ time a target data request ~~and~~ is issued to the actual reading and retrieval of the target data.
- Due to the operational nature of the magnetic tape system, target data searching within a particular data track 400 is undertaken at read ~~speeds, these~~ speeds. The read speeds ~~being~~ are dictated by the read head and the processing power of the tape ~~drive, such a~~ drive. This constraint ~~serving to increase~~ increases the above ~~identified~~ searching time period. An additional problem associated with the necessity to engage the read/write head is the excessive reading of data and data position information on data tracks in an attempt to locate the target data, as ~~detailed in~~ described in connection with Fig. 6. The magnetic tape, although generally long lasting, is subject to deterioration ~~in the event~~ as a result of excessive tape motion and engagement by read/write heads. Excessive reading operations also reduce the lifetime of the read head.

[0014] The inventors have ~~recognised~~ recognized a need for a magnetic tape data storage system having a ~~centralised~~ centralized data position information storage utility capable of storing data position information relating to data distributed ~~across the~~ along a linear tape. Such a system ~~being~~ is capable of providing a data position information storage area that can be loaded and unloaded separately ~~to~~ from the data stored on the tape. The method and apparatus of such a system having an accelerated target data searching utility ~~in relation to that found in the art,~~ compared to the prior art is disclosed in detail herein ~~below~~.

~~Summary of the Invention~~ Summary of the Invention

[0015] The inventors, on ~~recognising~~ recognizing the various problems associated with prior art data storage systems, provide a magnetic tape data storage system having a ~~centralised~~ centralized data position information storage area ~~being~~ that is effectively a pseudo map of the data distributed ~~across~~ along the length of tape. By ~~utilising~~ utilizing data position information stored centrally, and not distributed ~~across~~ along the length of tape as found in the art, the inventors provide a robust data storage system capable of enhanced data access times following the receipt of a target data request from a host.

[0016] According to one ~~implementation~~ embodiment of the present invention, following receipt of a target data request from a host, the ~~centralised~~ centralized data position information storage area is accessed and the exact position of the target data, on the magnetic tape, is determined thereby necessitating a single tape displacement action to access this target data. This single tape displacement ~~being~~ is in contrast to the operational nature of prior art storage systems.

[0017] ~~Utilising a centralised~~ Utilizing a centralized storage area provides a data storage system capable of loading and unloading data position information, ~~at~~ for example, at the beginning and end of a data access session, respectively. According to further aspects of the present invention the ~~centralised~~ centralized storage area is configurable for updating during data access operations such that at the end of a user session the updated ~~centralised~~ centralized storage area ~~may~~ can be downloaded to a suitable reserve storage area where it remains dormant until ~~it~~ the centralized storage area is required by the storage device, at ~~upon~~ which time it is reloaded into the ~~centralised~~ centralized storage area for use in determining a target data position on the tape.

[0018] In another ~~implementation~~ embodiment of the present invention the ~~centralised~~ centralized data position information storage area is configurable to store data position information relating to selected groups of data distributed ~~across~~ along the length of tape. This type of formatting provides a ~~centralised~~ centralized storage area containing data position information relating to striped bands of data along the total length of the tape. This reduces the required capacity of the ~~centralised~~ centralized storage area due to the reduced resolution of the pseudo data map.

[0019] According to ~~a first~~ one aspect of the present invention ~~there is provided~~ a method of ~~centralised~~ centralized data position information storage and ~~utilisation comprising~~ utilization comprises the steps of:

[0020] arranging a byte stream of data into partitioned logical data;

[0021] storing data position information relating to said logical data in a reserve storage area;

[0022] transferring said information from said reserve storage area to a ~~centralised~~ centralized storage area, wherein said ~~centralised~~ centralized storage area is configured to store said information relating to substantially all said partitioned logical data; and

[0023] ~~utilising~~ utilizing said information in said ~~centralised~~ centralized storage area to locate ~~a~~ target data ~~being~~ that is part of said logical data.

[0024] According to ~~a second~~ another aspect of the present invention ~~there is provided~~ a method of storing and ~~utilising~~ utilizing data position information on a tape data storage device, ~~said method comprising~~ comprises the steps of:

[0025] arranging a byte stream of data into partitioned logical data and recording said logical data onto a length of tape;

[0026] storing data position information relating to said logical data in a reserve storage area;

[0027] transferring said information from said reserve storage area to a ~~centralised~~ centralized storage area located within said tape device, wherein said ~~centralised~~ centralized storage area is configured to store said information relating to substantially all said partitioned logical data; and

[0028] ~~utilising~~ utilizing said information in said ~~centralised~~ centralized storage area to locate ~~a~~ target data on said tape, said target data being part of said logical data; and

[0029] reading said target data using a read head.

[0030] According to a ~~third~~ further aspect of the present invention ~~there is provided~~ a data position information storage and ~~utilisation~~ utilization device ~~comprising~~ comprises:

[0031] partitioned logical data distributed ~~across~~ along a length of tape;

[0032] a ~~reserved~~ reserve storage area ~~to store~~ that stores data position information relating to said logical data;

[0033] a ~~centralised~~ centralized storage area ~~configured to store~~ that stores said information received from said reserve storage area, said ~~centralised~~ centralized storage area ~~being configured to store~~ storing information relating to substantially all said partitioned logical data; ~~and~~

[0034] a search algorithm ~~to locate~~ for determining the location of a target data on said tape; and

[0035] a read head configured to read said logical data on said ~~tape;~~ tape.

[0036] ~~wherein said~~ The device is operable, in response to a request for said target data, to locate said target data on said tape using said information in said ~~centralised~~ centralized storage area and to read said target data by using said read head.

[0037] According to ~~a fourth~~ an added aspect of the present invention ~~there is provided~~ a computer product stores a program ~~comprising~~ having program commands for ~~implementing a method of centralised data position information storage and utilisation, said method comprising the steps of:~~ causing a computer to perform the following steps:

[0038] arranging a byte stream of data into partitioned logical data;

[0039] storing data position information relating to said logical data in a reserve storage area;

[0040] transferring said information from said reserve storage area to a ~~centralised~~ centralized storage area~~, wherein said centralised storage area is~~ configured to store said information relating to substantially all said partitioned logical data; and

[0041] ~~utilising~~ utilizing said information in said ~~centralised~~ centralized storage area to locate ~~a~~ target data ~~being~~ that is part of said logical data.

[0042] According to ~~a fifth~~ an added aspect of the present invention ~~there is provided~~ a computer product stores a program ~~comprising program~~ having commands for ~~implementing a method of storing~~ causing a computer to store and ~~utilising~~ utilize data position information on a tape data storage device~~, said method comprising the steps of~~. The program causes the computer to:

[0043] ~~arranging~~ arrange a byte stream of data into partitioned logical data and ~~recording~~ record said logical data onto a length of tape;

[0044] ~~storing~~ store data position information relating to said logical data in a reserve storage area;

[0045] ~~transferring~~ transfer said information from said reserve storage area to a ~~centralised~~ centralized storage area located within said tape device, wherein said ~~centralised~~ centralized storage area is configured to store said information relating to substantially all said partitioned logical data; ~~and~~

[0046] ~~utilising~~ utilize said information in said ~~centralised~~ centralized storage area to locate a target data on said tape, said target data being part of said logical data; and

[0047] ~~reading~~ read said target data using a read head.

~~Brief Description of the Drawings~~ Brief Description of the Drawing

[0048] For a better understanding of the invention and to show how the same may be carried into effect, there will now be described by way of example only, specific embodiments, methods and processes according to the present invention with reference to the accompanying drawings in which:

[0049] Fig. 1 ~~illustrates a~~, as described, is an illustration of a prior art tape data storage device ~~being~~ connected to a host;

[0050] Fig. 2 ~~illustrates schematically a~~, as described, is a perspective view of a prior art tape data storage cartridge of a single reel type containing an elongate magnetic tape data storage medium;

[0051] Fig. 3 ~~illustrates schematically operation~~, as described, is a schematic diagram of a prior art tape data storage device for reading and writing data to a tape data storage medium inserted into the device~~, as is known in the prior art~~;

[0052] Fig. 4 ~~illustrates~~, as described, is a schematic diagram of a length of prior art magnetic tape configured to store logical data and logical data position information;

[0053] Fig. 5 ~~illustrates the~~, as described, is a schematic diagram of a prior art arrangement of data position information ~~storage~~ stored within a ~~prior art~~ data storage device;

[0054] Fig. 6 ~~illustrates~~, as described, is a schematic diagram of an operational mode of a prior art data storage device ~~being operable to access~~ for accessing data following a data request from a host;

[0055] Fig. 7 ~~illustrates a logical pipeline,~~ is a block diagram of tape recording system having a logical media ~~having~~ with a ~~centralised~~ centralized storage area and a physical pipeline according to ~~a specific implementation~~ one embodiment of the present invention;

[0056] Fig. 8 ~~illustrates a portion~~ is an illustration of a data table of the ~~centralised~~ centralized data position information storage area ~~being a data table.~~ of Fig. 7;

[0057] Fig. 9 ~~illustrates~~ is a flow diagram ~~detailing~~ of the general operational nature of the data storage ~~system.~~ system of Fig. 7;

[0058] Fig. 10 ~~illustrates~~ is a schematic diagram including the relationship between a start position and a data target in terms of a logical displacement ~~and a~~ and physical displacement on a tape;

[0059] Fig. 11 ~~illustrates~~ is a schematic diagram including a length of magnetic tape ~~being~~ partitioned into selected data groups;

[0060] ~~Fig.~~ Figs. 12a ~~illustrates the initial stages~~-12c, together, are a flow diagram ~~of a flow diagram describing the operational mode of the storage device~~ according to a specific ~~implementation~~ method of operating the system of Fig. 7; and

~~Fig. 12b illustrates a continuation of Fig. 12a detailing the operational mode of the storage device according to a specific implementation;~~

[0061] ~~Fig. 12c is a further continuation of Fig. 12a detailing the operational mode of the storage device according to a specific implementation;~~

[0062] ~~Fig. 13a illustrates~~ Figs. 13a-13d, together, are a flow diagram ~~detailing the initial stages~~ of ~~the~~ a search algorithm ~~configured to locate~~ for locating a data target according to a specific ~~implementation~~ embodiment of the present ~~invention;~~ invention.

~~Fig. 13b illustrates a continuation of the flow diagram as detailed in Fig. 13a;~~

~~Fig. 13c is a further continuation of the flow diagram as detailed in Fig. 13a;~~

~~Fig. 13d is a further continuation of the flow diagram as detailed in Fig. 13a.~~

~~Best Mode for Carrying Out the Invention~~ Detailed Description of the Drawing

[0063] There will now be described by way of example the best mode contemplated by the inventors for carrying out the invention. In the following description numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent however, to one skilled in the art, that the present invention ~~may~~ can be practiced without limitation to these specific details. In other instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the present ~~invention~~ disclosure.

[0064] ~~Referring to~~ Fig. 7 ~~there is illustrated three components of~~ includes a data formatting channel 700 ~~according to a specific implementation of the present invention. The channel 700 comprises~~ responsive to data from a host device. Channel 700 comprises a logical data pipeline 701 ~~being~~ responsive to data from the host and operative to (1) perform logical formatting of user data ~~and to~~ and (2) compress user ~~data;~~ data. Pipeline 701 drives a ~~host a~~ host including logical media ~~702; and a~~ that in turn drives physical pipeline or channel 704. The user data ~~on~~ from the host device, after passing through ~~the~~ logical pipeline 701, is partitioned into data set ~~form, the~~ form. The compressed data is then transferred to logical media 702, configured with an updateable ~~centralised~~ centralized data position information storage area ~~703; storage~~ 703. Storage area 703, when constructed, ~~being~~ is effectively a pseudo data position map of logical data stored on a length of magnetic tape. ~~The logical media 702~~ Storage area 703 holds a logical representation of the data stored on tape, ~~in the storage area 703~~ in the form of ~~an~~ index data.

[0065] The channel 700 is ~~then~~ divided into a physical pipeline ~~703, being~~ or channel 704 that is operative to format the logical data into a physical format such that the data from channel 704 are written by write head 705 onto tape 706 as elongated parallel tracks, similar to tracks 400 (Fig. 4). The parallel elongated tracks 400 written onto tape 706 are illustrated in Fig. 10 and can be written to a length of magnetic tape in a predetermined format.

[0066] The components 701, 702 and 704 ~~may~~ can be ~~implemented in the best mode as~~ firmware, e.g. an application specific integrated circuit, ~~or as~~ or code.

[0067] ~~According to the specific implementation of the present invention the logical~~ Logical media 702 is a dynamic random access memory (DRAM), ~~such~~ (i.e., a volatile storage area memory) ~~being volatile, in~~ such that information stored within the storage area may not be retained in the event of a termination of power to the logical media.

[0068] The logical data received from a host is formatted in the logical pipeline 701 to provide partitioned logical data~~, this~~. This partitioning ~~being~~ is in terms of individual records and filemarks. The formatted logical data, being in ~~a~~ data set form, is then passed through the logical media 702 and into the physical pipeline 704. The physical pipeline 704 is configured to add error recovery information to each data set before ~~being~~ each data set is written onto tape. The data sets are written onto the tape according to the next available piece of tape for storing data. ~~The~~ Because the data sets~~, according to the specific implementation of the present invention, are~~ do not necessarily always have the same physical size, ~~and accordingly~~ a different number of data sets ~~may~~ are likely to be written on different physical data tracks.

[0069] ~~According to the specific implementation of the present invention data~~ At some stage prior to the receipt of a target data request issued

by a host, position information is loaded into the ~~centralised~~ centralized data position information storage area 703 from a reserve storage area, for example, a cartridge memory device~~, at some stage prior to the receipt of a target data request issued by a host. In further specific implementations of the present invention~~. Alternatively the ~~centralised~~ centralized data position storage area 703 accumulates data position information as the data is processed according to pipelines 701 and 704. Once data position information is stored in the storage area 703 it can, at some future stage, be transferred or downloaded to a suitable reserve storage area for future use.

[0070] ~~Referring to~~ Fig. 8 ~~there is illustrated~~ includes an illustration of a portion of the ~~centralised~~ centralized data position information storage area 703 forming part of the logical media 702. The storage area 703 comprises a data table ~~being~~ configured to store logical data position information relating to logical record data and logical file mark data. The logical data position information located ~~within~~ in the data table 703 is arranged such that a logical data position has a corresponding physical position on the magnetic tape~~, such a~~ and a physical data set number. The physical position ~~being~~ is in terms of a physical track number ~~and a physical data set number, such~~. These physical parameters ~~being~~ are relative to the BOW or EOW. The logical data position information contained within the data table 703 ~~may, according to the specific implementation of the present invention relate~~ relates to all data distributed ~~against~~ along the length of tape. ~~In a further specific implementation of the present invention~~ Alternatively, the logical data position information within the data table 703 corresponds to selected data ~~groups, such~~ groups. Such data groups ~~being~~ are spatially distributed ~~across~~ along the length of magnetic tape. The benefit of storing data position information relating to selected data is that the storage area 703 requires less capacity within the logical media 702 for data position information storage.

[0071] Fig. 9 ~~illustrates~~ is a flow diagram ~~detailing~~ of the general mode of operation of ~~the specific implementation of the present invention~~ apparatus of Figs. 7 and 8. Following the initial writing of data received from a host onto the length of magnetic tape, and the loading into the ~~centralised~~ centralized data position information storage area ~~with~~ of data position information, a target data request is received from a host ~~at stage~~ during step 900. Such a target data request ~~being~~ is issued, for example, by a user requiring specific data for use, for example, in an application. The data request of step 900 requires the tape drive, and in particular a read head forming part of the drive, to access the target data and transfer or output this data to the host. Following step 900, the operation continues to step 901, during which the~~The~~ logical data position and the physical data position of this target data ~~is~~ are determined by the logical media 702 via the centralised data position information storage area ~~at stage 901. The~~. Then during step 902 the logical media 702, having a searching utility in the form of a searching algorithm, determines the tape motion required to allow the read head forming part of the tape ~~drive,~~ drive to access the target data ~~at stage 902~~. The tape motion determined by the logical media 702 is based on the current tape drive position, defined by logical positional parameters (records and file marks), logical data position information within the storage area 703, and an ~~estimation~~ estimate made by the search algorithm, of the position of the target data. The logical media 702 calculates the required tape motion to, for example, change data tracks and data sets, to access a record or plurality of records ~~(being. The~~ accessed record or plurality of records is referred to as the target ~~data)~~ data. If the ~~centralised~~ centralized data position information storage area contains information relating to substantially all the data recorded ~~onto~~ on the magnetic tape, the ~~estimation~~ estimate of the target data position is an actual determination of the target position and, as such, the read head can be positioned over the target data requiring a single tape displacement motion. However, if ~~according to further specific implementations of the present invention,~~ the logical data position information is stored in the storage area 703 ~~relating~~ and relates to selected groups of data distributed ~~across~~ along the length of tape, ~~it is envisaged that~~ the

target data request relates to data ~~not having~~ that does not have its position stored in the storage area 703. In such a scenario the read head ~~is required to perform localised~~ performs localized iterative searching operations to ~~locate~~ find this target data in close proximity to the estimated position ~~undertaken at~~ determined by logical media stage 702. Such searching is undertaken as the ~~data~~ tape is ~~transported passed~~ translated past the read head~~, due to, in this specific embodiment, the displacement of the magnetic tape~~.

[0072] ~~At stage 903~~ After step 902 has been completed the tape motion is initiated during step 903, during which ~~to allow~~ the read head ~~to access~~ accesses the target data or estimated target data on the magnetic tape. Once the target data is found ~~at stage~~ during step 904 the data is processed by the logical media ~~at stage~~ 702 during step 905.

[0073] ~~Referring to~~ Fig. 10 ~~there is illustrated a logical data position of target data B relative to a starting logical data position A together with the actual physical data positions of B and A on a length of magnetic tape~~ includes an exemplary situation wherein the target data has a logical position B along a hypothetical elongated track. The starting logical data position has a position A on the hypothetical elongated track. Fig. 10 also includes the actual physical position of the starting data, at position A' on the second elongated data track 400 of tape 706, and the actual physical position of the target data, at position B' on the third elongated track of tape 706. Physical position B' is behind physical position A' in the direction of motion of tape 706 (i.e., position B' is closer to BOW than position A'). In contrast logical position B is in front of logical position A on the hypothetical track. ~~The~~ In the example of Fig. 10, the logical media 702 is ~~illustrated in Fig. 8, having~~ considered to have just received a target data request from a host ~~and as~~. As such, following the ~~estimation~~ estimate of the logical target data position (B), the read head moves from starting logical data position A to this new target logical position B.

[0074] In terms of the physical data position ~~of B~~ B' relative ~~to A~~ to physical data position A' on the magnetic tape, and ~~as illustrated in Fig. 8 the logical media, and in particular,~~ the read head must traverse back from position A' along ~~a~~ the second data track 400, ~~swap~~ move to the third data ~~tracks~~ track and continue traversing back towards the ~~beginning~~ Beginning of Wrap or tape (BOW) arriving ultimately at position B'. The logical media 702~~, according to the specific implementation of the present invention~~ determines (1) the physical data position of the target data with reference to a data set number and track number and ~~also determines~~ (2) the logical data position with reference to a record number and a filemark number. The traversing of the logical media from physical position A' to physical position B', as illustrated in ~~Fig. 8~~ Fig. 10, is possible due to the data position information contained in the updateable ~~centralised~~ centralized data position information storage area 703 ~~– this area containing~~ that contains useful data position information to determine the physical target data position B'.

[0075] The physical ~~data~~ position B' of the target ~~B is~~ data is determined by the logical media accessing logical data stored in the storage area 703. The physical position B' of ~~a target~~ the target data is determined by the arrangement of logical data within the data table (Fig. 8) of the storage area ~~703, the~~ 703. The data table ~~being arranged according to a specific embodiment of the present invention in~~ includes columns of record numbers and file ~~marks, such~~ marks. The records and file marks ~~being~~ are related to a physical data set on a physical data track by ~~the~~ inclusion ~~within~~ of the records and file marks in a particular row of the data table.

[0076] ~~Referring to~~ Fig. 11 ~~there is illustrated the storing of~~ is a schematic diagram illustrating how selected logical data position information relating to selected and partitioned logical data are distributed and stored along the length of magnetic tape, according to a further ~~specific implementation~~ embodiment of the present invention. The ~~centralised~~ centralized data position information storage area 703, according ~~to a~~ to the further ~~specific~~

~~implementation, is configured to store~~ embodiment, stores data position information relating ~~to a~~ to the percentage of ~~the~~ total partitioned logical data distributed ~~across~~ along the length of the tape. ~~The centralised~~ Because the centralized storage area 703 ~~having~~ has an incomplete pseudo map of the logical data on tape, area 703 requires ~~reduced~~ less capacity for storing such information ~~storage and accordingly~~ . Accordingly the capacity of the logical media ~~may~~ can be ~~utilised~~ utilized for additional applications. The tape illustrated in Fig. 11 ~~illustrates~~ includes a ~~centralised~~ centralized storage area 703 having a data table (as illustrated in Fig. 8) that stores data position information ~~stored in its data table~~ relating to logical data distributed ~~across~~ along the length of ~~tape~~ the tape. The logical data are stored in selected data groups 1100, ~~such~~ that are spaced from each other along the lengths of tracks 400, each of which extends parallel to the edges of the tape. Each of data groups ~~being~~ 1100 is effectively, ~~according to the further specific implementation of the present invention,~~ stripes of data as illustrated in Fig. 11. Logical data position information relating to data not within the selected data group 1100 is not stored in the storage area 703.

[0077] The logical media 702, when requested to access ~~a~~ target data not falling within a selected data group 1100, and whose data position information is not stored within the storage area 703, ~~must perform~~ performs an effective local search~~, to~~ to access such data using the data position information of data within a nearest selected data group 1100. In such a scenario the logical media 702 determines ~~a data~~ the position of data having data position information stored in the storage area 702, such information relating to data within a selected data group 1100. The read head is then positioned over such data (within a selected data group) ~~the~~. The logical media then scans the ~~tape,~~ tape in a first tape motion direction, to locate the target data. It will be appreciated, by those in the art that the furthest physical displacement of the tape during any particular ~~localised~~ localized search, is the displacement from one selected data group ~~to a~~ to the next nearest neighbor selected data group 1100. According to ~~yet further specific implementations of the present invention~~ another embodiment the

distance between selected data groups 1100, along the length of tape, ~~may be~~ is small so as to reduce the time taken for ~~localised~~ localized data searching.

[0078] Conversely, and to ~~minimise~~ minimize the amount of information stored within the storage area 703, data position information stored within the storage area 703 ~~may relate~~ relates to relatively narrow selected data groups 1100 distributed along the length of ~~tape whereby the~~ tape. Such relatively narrow selected data groups 1100 are separated from each other by relatively large distances~~, such formatting requiring a possible~~. Formatting of data of relatively narrow selected data groups 1100 distances generally results in an increased time period ~~for a~~ for target data to be located during a local search.

[0079] ~~According to the specific implementation of the present invention the storage~~ Storage area 703 is configured with logical data position information related to substantially all the partitioned (in terms of data sets) logical data distributed ~~across~~ along the length of ~~tape, such~~ tape. The partitioned logical data is not ~~being~~ divided into selected data groups 1100 as illustrated in Fig. 11. The logical media 702 having the effective pseudo map of the partitioned logical data distributed along the length of tape ~~can identify~~ identifies the logical and physical position ~~of a~~ of target data, without the need to resort to ~~localised~~ localized searching being conducted between neighboring selected data groups 1100 as identified above.

[0080] ~~Referring to~~ Fig. 12a ~~there~~ is ~~illustrated~~ a flow diagram detailing the initial stages of an ~~initialisation~~ initialization procedure following which the ~~centralised~~ centralized data position information storage area 703 contains data position information relating to logical data distributed ~~across~~ along the length of tape. A length of tape is loaded onto a spool or reel within the storage system ~~at stage~~ during step 1200. ~~The~~ Then during step 1201 the logical media 702 ~~then~~ performs a check procedure to determine if data position information is stored within a reserve storage area ~~at stage 1201~~. Such a reserve

storage area ~~being~~ is any of (1) a suitable cartridge memory (CM) connected to or forming part of the storage system, (2) a suitable storage area located on the ~~tape or~~ tape, (3) a further storage area positioned within the storage system or ~~being~~ (4) a further storage area that is a separate entity connected by suitable connecting means. If data position information is found within the storage area, the data position information is (1) read by the logical media ~~at stage~~ during step 1202 and (2) subsequently written to the storage area 703 ~~at stage~~ during step 1203. Following the loading of data position information into the storage area 703 ~~at stages~~ during steps 1202 and 1203, the data table forming the storage area 703 contains information relating to the position of logical data distributed along the length of ~~tape, the~~ tape. The data table ~~being~~ is an effective pseudo map of the logical data that the magnetic tape stores. The logical media is configured to possibly delete data within the reserve storage area ~~1204, such~~ (step 1204). Such data deletion ~~being~~ during step 1204 is a preparatory stage in the event of a subsequent information download from the storage area 703 to the reserve storage area. Conversely, the data position information within the reserve storage area ~~may~~ can be preserved ~~at stage 1205, such~~ during step 1205. Such data position information is thereby ~~being~~ available for future ~~utilisation~~ utilization by the logical media ~~through stages~~ during steps 1202 and 1203.

[0081] ~~Following stage 1201 in which the logical media checks for data within the reserve storage area, if~~ If during step 1201, it is found that no data exists in ~~this~~ the reserve storage area 703, data position information relating to data distributed along the length of tape~~, must be~~ is loaded into storage area 703 from a separate location. Such a procedure is ~~detailed with reference to~~ performed by the steps in the flow chart of Fig. 12b. In the event of an initial blank reserve storage area 703, data position information ~~may be~~ is loaded from a suitable CM ~~at stage~~ during step 1206. ~~The~~ During step 1207, the logical media 702 is also configured to ~~received~~ receive data position information loaded from the directories 401 located on the tape at, for example, the BOW or EOW,

~~at stage 1207~~. Such directories ~~containing~~ contain data position information relating to the logical data distributed along the length of the tape as illustrated ~~with reference to~~ in Fig. 5.

[0082] Following the loading of data position information into storage area 703, forming part of the logical media 702, the storage system ~~is configured to receive an~~, during step 1208, receives a command from a host to locate and provide access ~~to a~~ to target data ~~at stage 1208~~. Using a suitable search algorithm, as detailed with reference to Figs. 13a – d, the logical media ~~utilises~~ 702 utilizes the data position information within the storage area 703 to process target data requests ~~at stage 1209 whereby~~ during step 1209. Hence, during step 1209 target data is transferred from the storage system to a host. ~~When in~~ In operation, the storage system is configured to perform multiple target data requests ~~utilising~~ utilizing data position information within the logical media. A shut down command is then issued by the host ~~at stage~~ during step 1210, causing data position information ~~is~~ to be then downloaded to the reserve storage area ~~at stage~~ during step 1211. Data position information ~~within~~ in this reserve storage area ~~may~~ can then be used for subsequent ~~initialisations~~ initializations of the logical media as detailed ~~with reference to~~ in Fig. 12a. ~~According to the specific implementation of the present invention~~ Because the logical media 702 is preferably a dynamic random access memory (DRAM), ~~such that as~~ unloading the tape ~~is unloaded~~ from the storage system ~~at stage~~ during step 1212, does not result in the logical media ~~does not retain~~ retaining information relating to a previously loaded tape.

[0083] ~~With reference to Fig. 12a,~~ Fig. 12c ~~details the further procedure~~ is a flow chart of the steps following the loading of data position information from the reserve storage area to the storage area 703 within the logical media 702. The storage system having ~~a~~ the logical media configured with ~~a~~ the data table comprising data position information relating to logical data distributed along the length of tape, is now configured to receive a target data

command from a host ~~at stage 1208 following~~ during step 1208. Following the receipt of such a target data command the logical media 702, as detailed above, conducts target data processing ~~at stage~~ during step 1209. Following the undertaking of a single or multiple target accessing operations, the host issues a shut down command ~~is issued from the host at stage 1210, such a~~ during step 1210. The shut down command ~~being followed by the~~ causes a loss of power to the logical media~~. In the event of~~ 702, step 1216. If the logical media, and in particular, the storage area 703 ~~being~~ is a volatile memory (DRAM), data position information ~~may~~ can be downloaded from this storage area to a suitable reserve storage area in order to preserve the data position information. Accordingly, data position information within the storage area 703 is written to the reserve storage area ~~at stage 1213.~~ during stage 1214.

[0084] The ~~transferring~~ transfer of data position information ~~at stage 1213 would be~~ during step 1215 is appropriate if~~, according to further specific implementations of the present invention,~~ the logical media 702 is configured to update the storage area 703 with data position information relating to data ~~having been~~ that were updated on the length of tape. ~~According to~~ In this ~~further specific implementation of the present invention,~~ arrangement, the logical media ~~is configured to update~~ 702 updates the storage area 703 with data position information during a target data access operation following ~~the~~ receipt of a target data command issued by a host. In the event of a ~~centralised~~ centralized storage area 703 having incomplete data position information relating to logical data stored on tape, the logical media 702 is configured to dynamically build the storage area with data position information each time the tape is displaced and a data read operation undertaken. The updating of the storage area 703 ~~being~~ is possible though the ~~utilisation~~ utilization of a suitable update algorithm or algorithms ~~being~~ that are operative to (1) determine a logical data position and physical data position with reference to a known position and ~~to~~ (2) store this new data position information within the ~~centralised~~ centralized storage area 703.

[0085] According to an alternative procedure ~~of the specific implementation,~~ in response to a shut down command from the host (step 210) data position information within storage area 703, ~~following the command to shut down from the host at stage 1210~~ is not written to the reserve storage area ~~at stage 1214. The step of~~ during step 1214; the not writing step is shown by step 1215 on the flow region of Fig. 12c. By not writing data to the reserve storage area ~~may, for example, may be required in the event of,~~ problems associated with corrupted data ~~being corrupted~~ within the ~~centralised~~ centralized storage area 703 are avoided. In such an event, the corrupted data within the storage area 703 following the unloading of the tape ~~at stage~~ during step 1212 ~~would be~~ are lost such that the storage area 703 ~~could~~ can then be loaded with uncorrupted data position information from a suitable reserve storage area.

[0086] ~~Referring to~~ Fig. 13a ~~there~~ is ~~illustrated~~ a flow diagram detailing the initial stages of ~~a~~ data retrieval by the logical media 702 from a magnetic tape data storage medium. Initially, the tape is loaded into the storage system ~~at stage~~ during step 1200. A target data request is then received from a host ~~at stage~~ during step 1208. The logical media 702 then, during step 1300, checks the ~~centralised~~ centralized data position information storage area 703 for complete data position information relating to substantially all the partitioned logical data distributed along the length of tape ~~at stage 1300~~.

[0087] If the ~~centralised~~ centralized data position information storage area 703 contains data position information relating to~~, for example,~~ selected data groups distributed along the length of tape (an incomplete storage area), the logical media ~~must perform~~ 703 performs at least one ~~localised~~ localized search ~~in order~~ to determine the target data position based on data position information ~~which relates~~ relating to data ~~being~~ positioned in close proximity to the target data on the magnetic tape. In the event of an incomplete ~~centralised~~ centralized storage area 703, ~~according to the further specific implementation of the present~~

~~invention,~~ the logical media 702 establishes the current position ~~at stage 1301, the~~ during step 1301. The current position ~~being~~ is represented in terms of logical data position parameters (record numbers and file mark numbers) and physical data position parameters (data set numbers and track numbers). The determination of the current position ~~being~~ is conducted by ~~the engagement of~~ engaging the read head forming part of the tape drive. The logical media then, ~~makes an estimation of the~~ during step 1302, estimates the target data position ~~at stage 1302~~ based on the current position parameters and any useful data position information within the storage area ~~703, such~~ 703. The useful data position information ~~being in particular, information relating~~ relates to data located in close proximity to the target data position on the magnetic tape. ~~The~~ Then, during step 1303 the estimated target data position is ~~then~~ compared with the current position ~~at stage 1303 if~~. If the estimated target data position is greater than the current position, the system advances to step 1304, Fig. 13b. In step 1304 the logical media, via the tape drive, changes its current position within a particular data set and on a particular data track to a current position + N ~~as detailed in Fig. 13b. Where~~, where N is an integer ~~and~~ dependent upon the physical layout of data tracks on the magnetic tape. ~~For example, the~~ The formatting of data tracks on the tape ~~according to the present invention, may take~~ takes the form of a series of parallel tracks running the length of the tape or alternatively a squashed square spiral in which data is first written onto the centre of the tape such that subsequently written data extends out from this central position in a square spiral. For example, the estimated target data position may be a factor of 10 greater than the current data position on the tape~~, and as such~~. If so, the tape drive via the logical media~~,~~ 702 displaces the tape (in terms of data sets and data tracks, by the appropriate parameter N). Following the change of position ~~as detailed at stage~~ of step 1304 the new data position of the logical media 702 on the tape is read ~~at stage 1305, this~~ during step 1305. This new position ~~being~~ is read in terms of physical track and physical data set number and logical record and logical file mark number. ~~Stages~~ Steps 1302 and 1303 are

then repeated in order to determine if the new physical data position is the desired target data position. ~~With reference to Fig. 13c if~~

[0088] If the estimated target data position is found during step 1103 to be not greater than the current position, the logical media ~~determines~~ 702 advances to step 1306 (Fig. 13c) to determine if the estimated target data position is less than the current position ~~at stage 1306~~. If the estimated target data position is found to be less than the current position, the logical media 702 determines (during step 1307) that the tape drive should change position from its current logical and physical data position to this current position – N~~, as detailed at stage 1307~~. Following such a change in position, the new data position is then (during step 1305) determined by the read head and logical media 702, in terms of track number, data set number, record number and file mark number~~, at stage 1305. A selected~~. After step 1305 operation returns to step 1302 and a number of the above ~~stages~~ steps are then repeated ~~in order~~ to determine if the target data position has been located. If ~~following stage 1306~~ it is determined during step 1306 that the estimated target data position is not less than the current data position, then the logical media 702 determines (during step 904) that the target data ~~is~~ has been found ~~according to stage 904~~, such that at this position the read head can then access the target data ~~at stage~~ during step 905.

[0089] ~~With reference to Fig. 13a,~~ Fig. 13d ~~details~~ includes the ~~subsequent~~ procedure following the determination ~~of~~ during step 1300 (Fig. 13a) that a complete data position information storage area ~~as detailed at stage 1300. According to the specific implementation of the present invention if~~ has been located. If the storage area 703 contains data position information relating to substantially all the partitioned logical data distributed along the length of tape, the logical media 702 establishes the current position ~~at stage 1301~~ during step 1301; steps 1301 of Figs. 13a and 13d are the same. The logical media 702 then ~~utilises~~, during step 902, utilizes the data position information within the storage area 703 to determine ~~a~~ the required tape motion to locate the target data ~~at~~

~~stage 902 when~~. When the read head is located over the target data ~~it can be~~, the target data are read and transferred to the host ~~at stage~~ during step 905.

[0090] As will be appreciated by those skilled in the art, the specific and further ~~implementations~~ embodiments of the present invention are configured for operation when ~~utilised~~ utilized in a storage system in which the tape drive is displaceable relative to the magnetic tape medium. Such a system, ~~utilising~~ utilizing a static tape with displaceable tape drive is operative to locate ~~a target~~ target data, following a request from a host, due to the availability of data ~~being able to be~~ that are transported ~~passed~~ past the read head of the tape drive.

[0091] The transporting of logical data ~~passed~~ past the read head is common to both operational methods of the storage system described herein, in which the tape drive is static and the magnetic tape is displaceable, and a system in which the tape drive is displaceable and the magnetic tape is static.

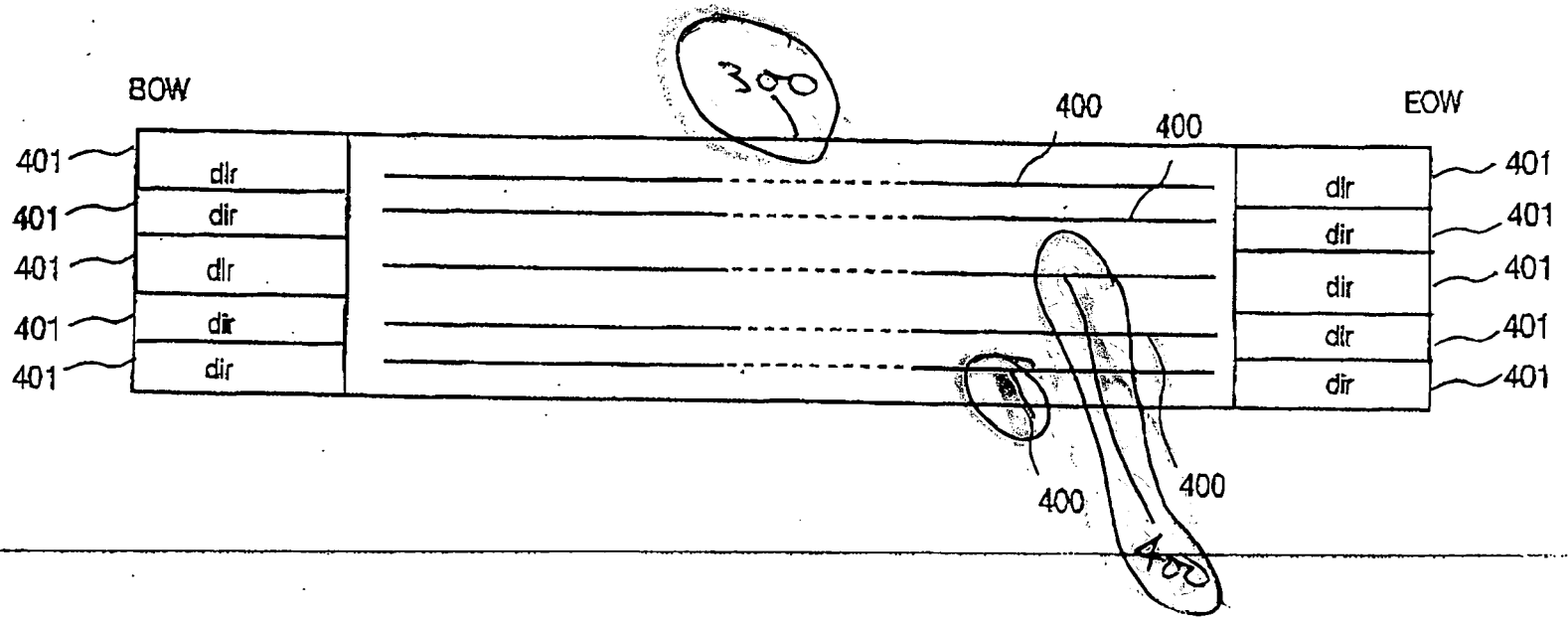

Fig.4
(Prior Art)

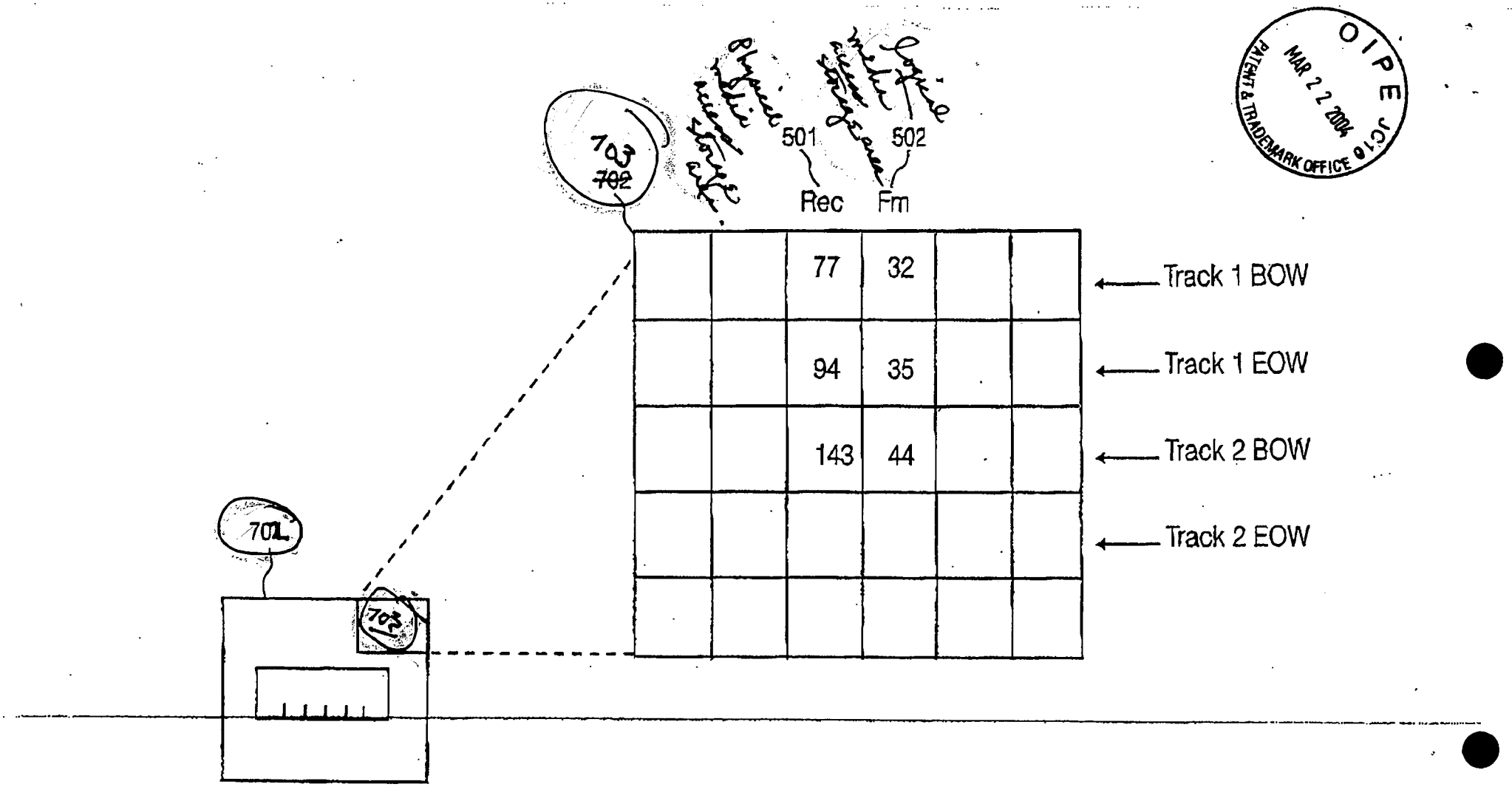

Fig.8

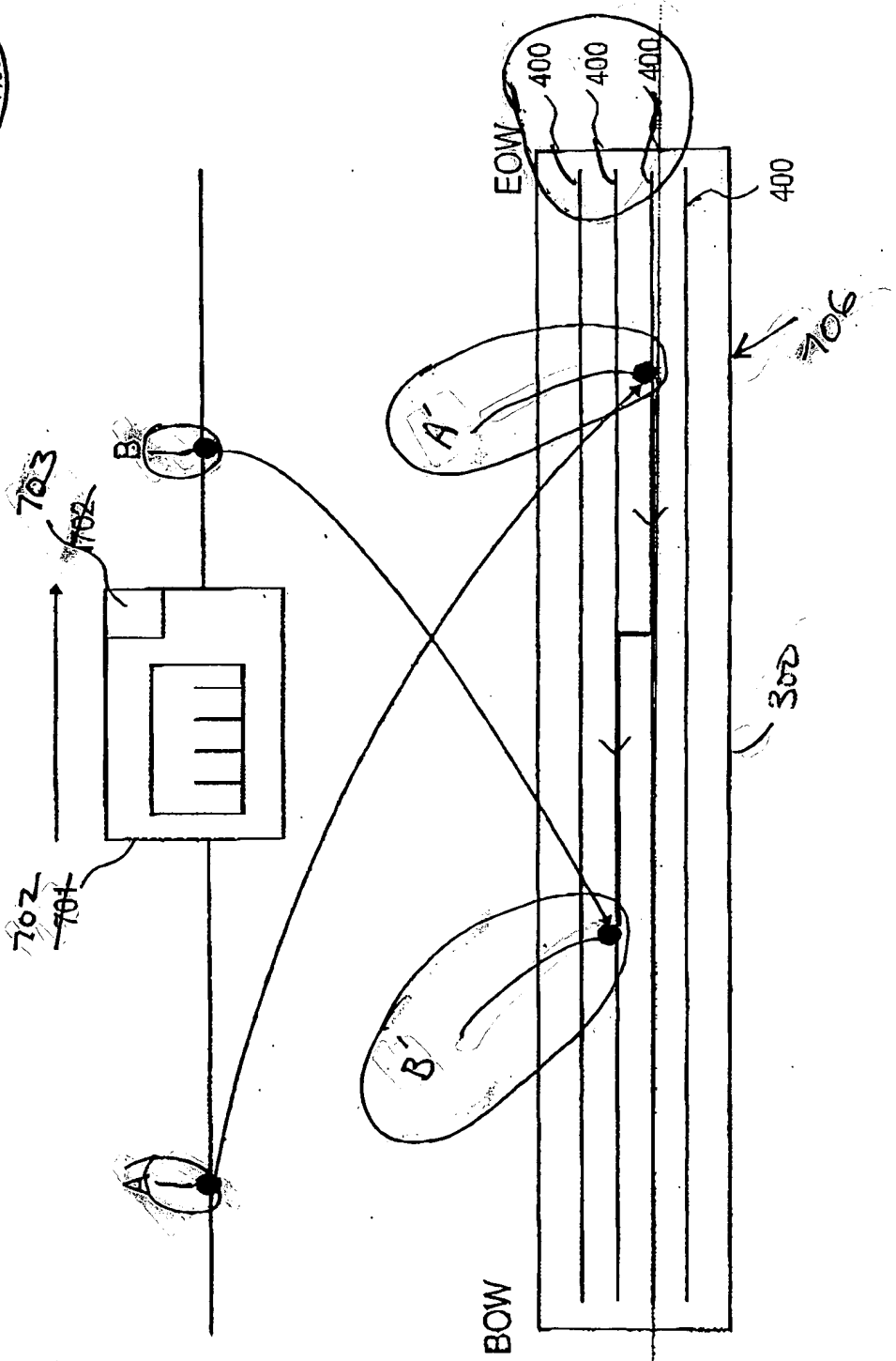

Fig.10

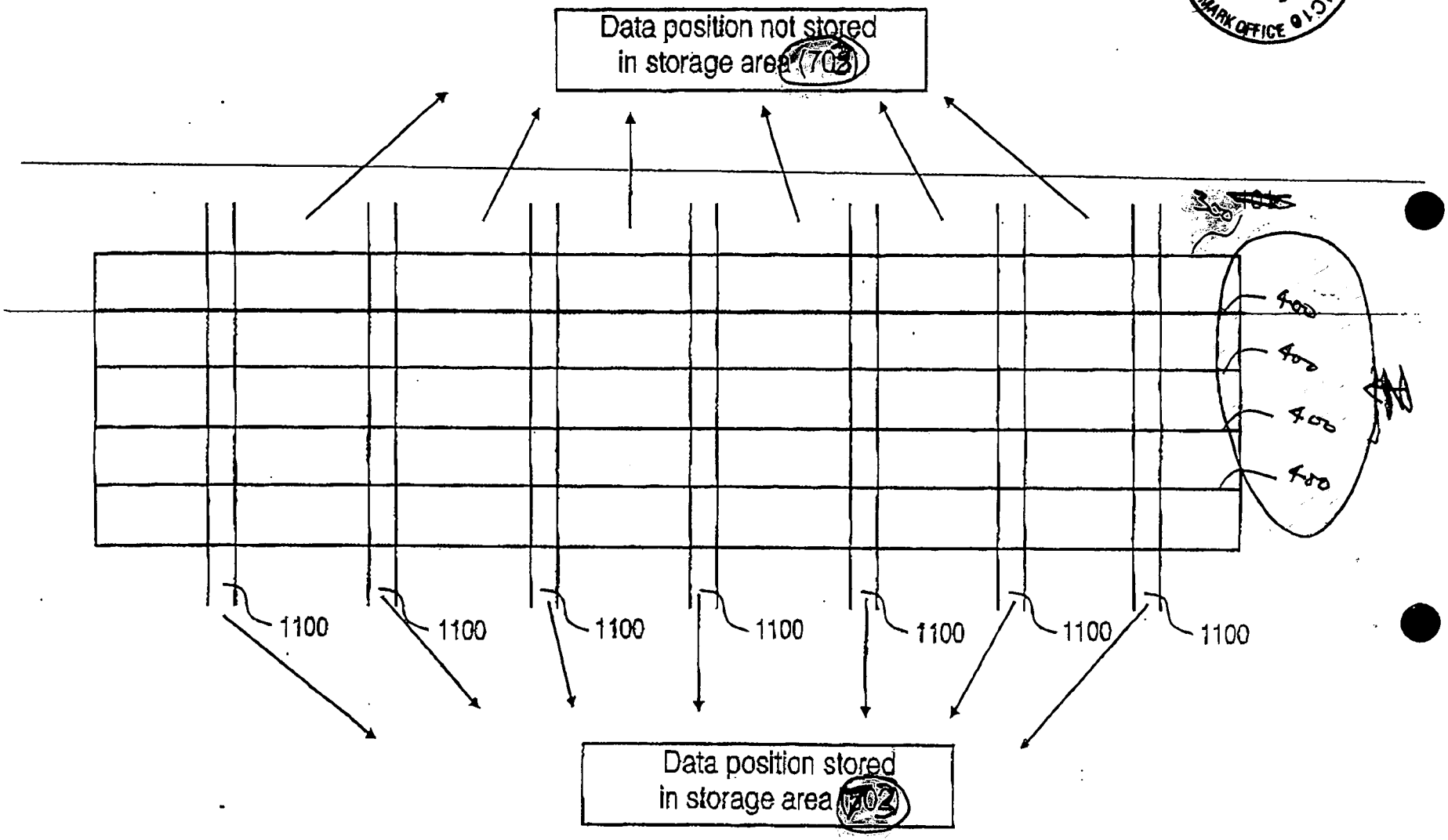

Fig.11

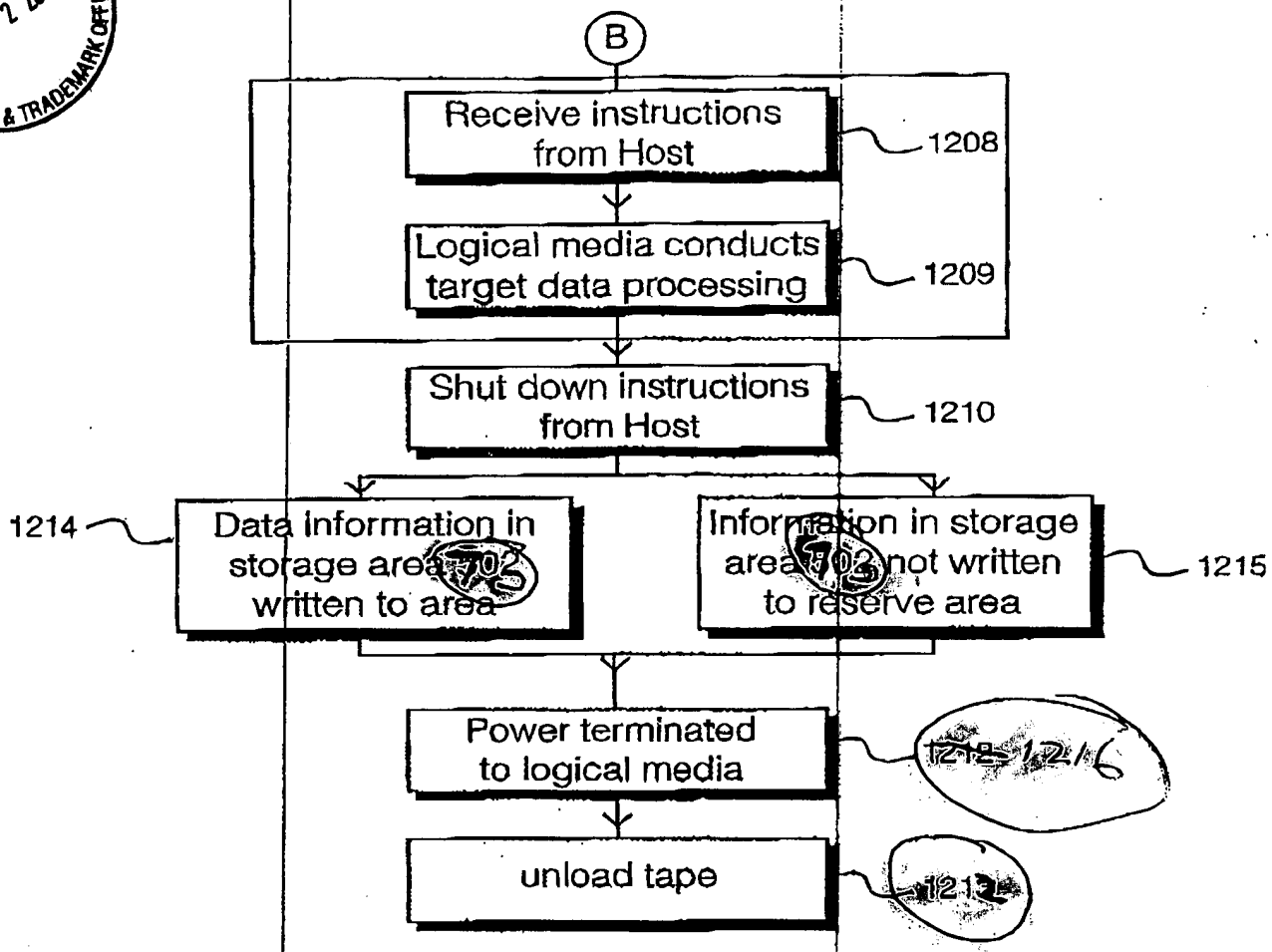

Fig. 12c